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Three-Phase Induction Motor Drive Control Structure

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***Abstract**: Industrial control systems require Field Programmable Gate Arrays (FPGAs) as an appropriate hardware integration. An implementation of these dynamically reconfigurable FPGAs enables digital replacement of traditional microcontrollers and DSPs to ensure fast functioning. A validation of FPGA-based implementation for DTCSVM control of induction motors appears in this research. A Xilinx System Generator functions within a MATLAB/Simulink platform to emulate the DTC-SVM control of induction motor drives.*

***Keywords**: FPGA, Xilinx System Generator, DTC-SVM, Induction Motor, MATLAB/Simulink*

I. Introduction

Direct torque control with space vector modulation (DTC-SVM) used for induction motor drives has shown rapid growth since the last few years. The SVM-DTC with low pass filter achieves three core characteristics: a constant switching frequency combined with minimal torque and flux ripple together with low current distortion [1-4]. Electronic Devices need to execute all required functions properly to implement electrical controller devices. Multiple industrial fields such as automotive and aerospace applications and space programs must satisfy a set of important performance standards. These standards include obtaining high concentration of targets along with the needed level of control integration. Multiple control operations function through a single device due to embedded systems with low cost and integrated controllers.

High-performance control algorithms are applied and the system provides flexibility to modify parameters while changing the controller strategy. Implementation occurs rapidly when designers use appropriate processes followed by quick real-time computations and achievement of accuracy and dependability in challenging operational conditions. FPGAs represent programmable integrated circuits that contain both configurable logic blocks and customizable interconnection components [6]. Engineers who build the devices can program them for execution of various extensive functional capabilities. FPGAs serve as development resources for ASIC prototypes and provide confirmation platforms that verify physical implementation of new algorithms. These controllers enter the market quickly and with affordable development costs so producers integrate them into finished products at a rapid pace.

FPGA technology delivered high-performance devices which included numerous millions of gates when it reached commercial markets in the early twenty-first century. The integration of high-speed input/output (I/O) ports as well as embedded CPU cores and similar features exists within multiple such devices. The current FPGAs serve as a base to execute every possible application including systems which combine hardware and software along with communication devices, software-defined radios and radars and image processing and digital signal processing (DSP) tasks.

II. Principles of DTC-SVM

Traditional DTC faces its main shortcomings because the SVPWM-based DTC framework uses load angle controls to minimize these issues. A single space vector emerges through typical space vector transformation of three-phase voltage systems. Space vector modulation method allows the application of required stator voltage vectors. The use of fixed switching frequency allows both zero steady state error and virtually non-existent torque ripple measurements to be achieved [7]. The control approach has an easy application process because it needs one PI regulator paired with a basic flux calculation block while omitting rotating coordinate translation. Figure 2 demonstrates this control block diagram example.

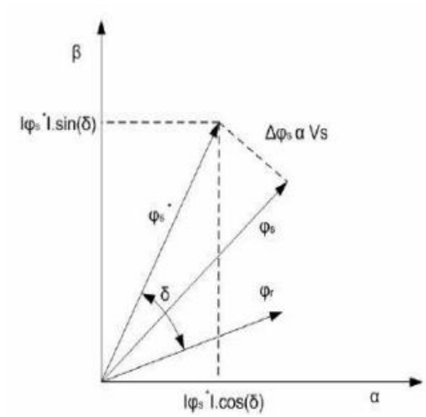

Fig 1: Reference and estimated flux relations

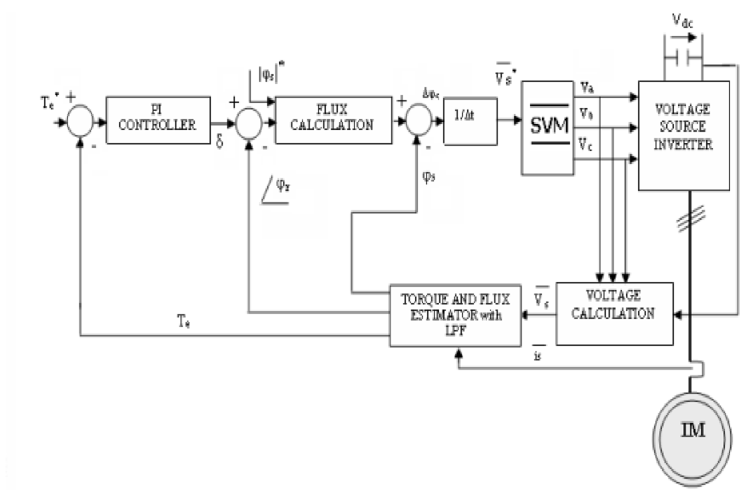

Fig 2: Block scheme of DTC-SVM with closed loop torque control

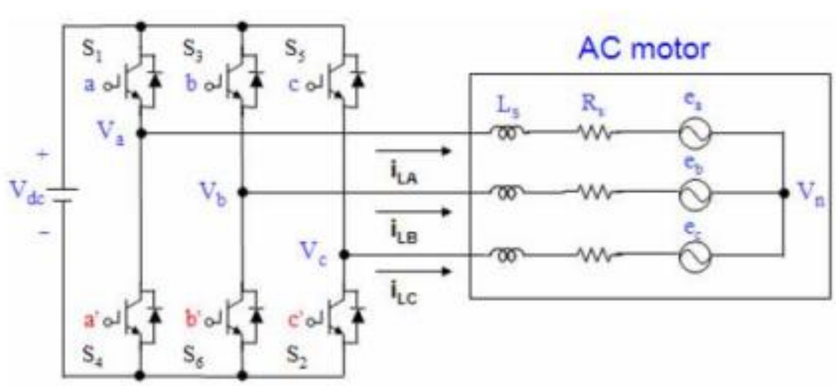

Fig 3: Three-phase voltage source PWM Inverter

III. PI Controller

There are a lot of PI controllers in every industry. They can take on a variety of shapes. Additionally, PI controllers are integrated into a variety of special purpose control systems. These controllers perform a number of crucial tasks, including feedback and steady state error elimination.

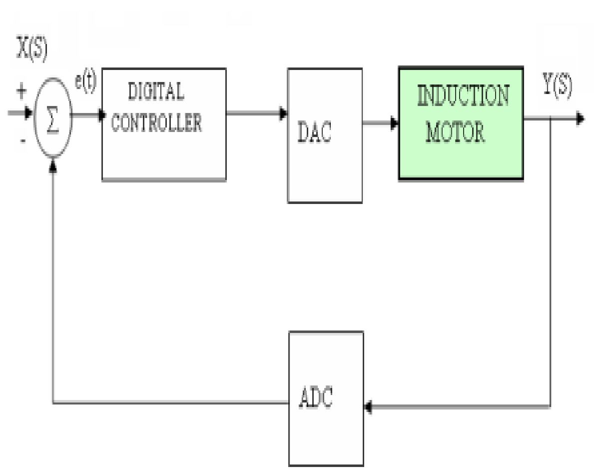

Fig 4: Block diagram of PI Control system

Figure 4 illustrates the representation of the torque control loop block diagram. A low-pass filter serves as the simplest solution to deal with the starting conditions and dc drift issues which occur in pure integrators. Figure 5 illustrates the block diagram of low-pass filter application.

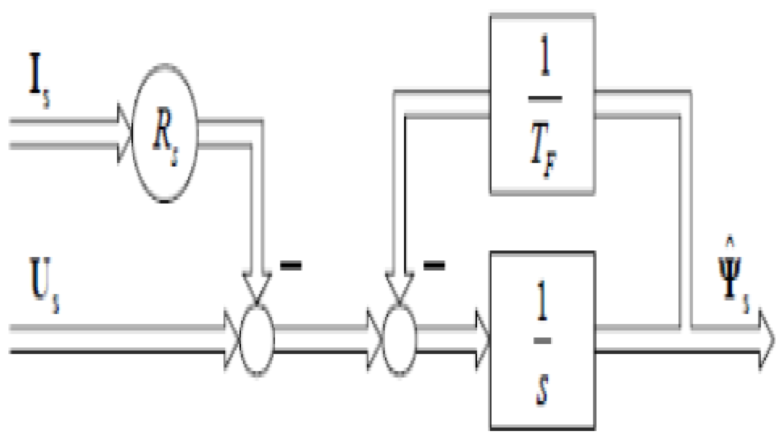

Fig 5: Flux Estimator based on voltage model with low-pass filter

IV. Design of PI Controller

The Xilinx System Generator serves to replicate the Module PI controller based on Figure 9. Users benefit from the graphical algorithm features of Xilinx system generator within MATLAB/Simulink to produce complex designs efficiently.

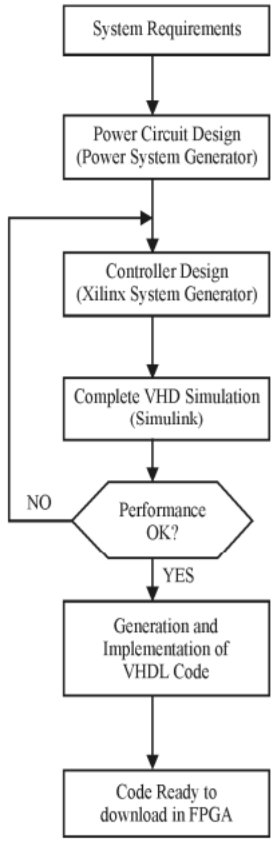

Fig 6: Induction Motor Drive Controller Design and Implementation Process

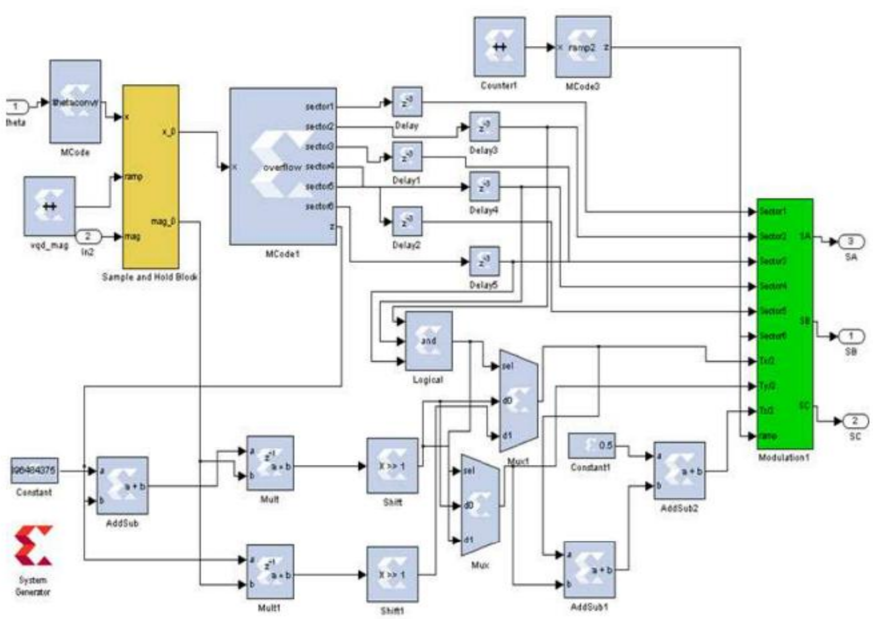

Fig 7: Xilinx Model of SVPWM

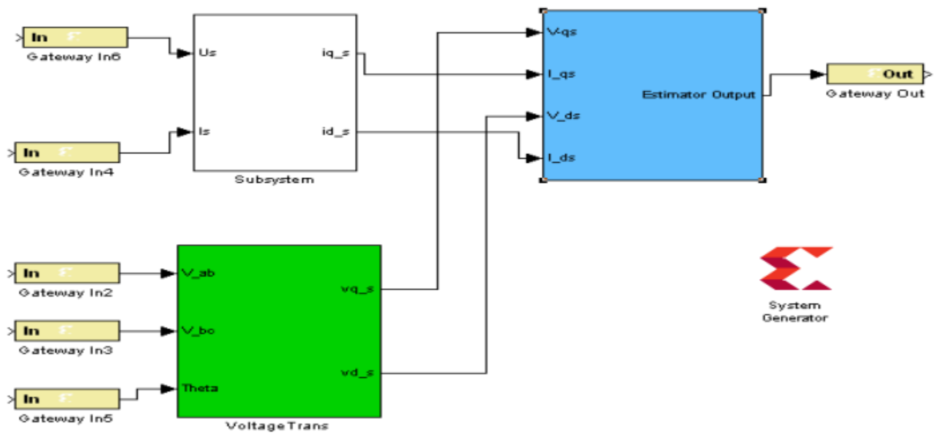

Fig 8: XSG and MATLAB/Simulink model of torque and flux estimation

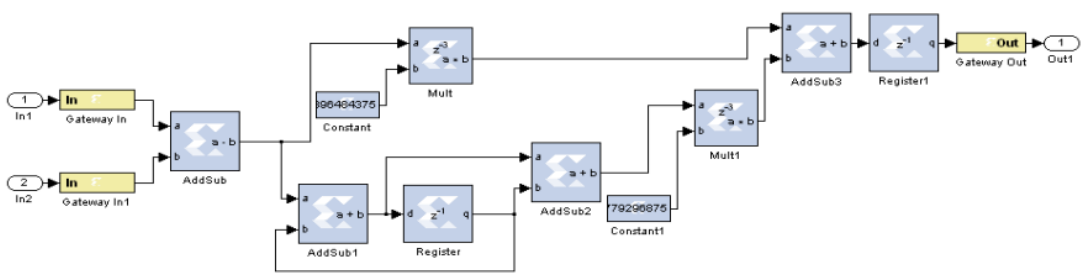

Fig 9: XSG model of PI controller

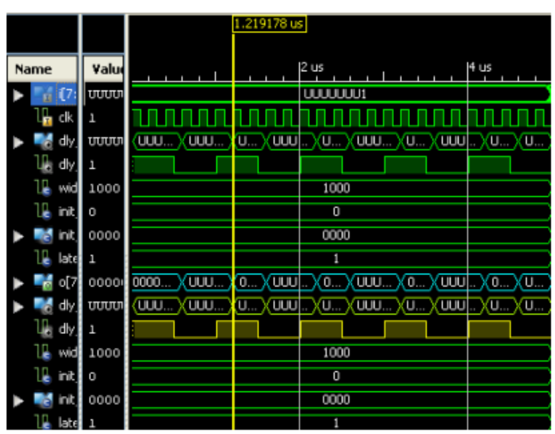

Fig 10: KSG simulation of torque and flux estimator with low pass filter

V. FPGA Simulation Results

The simulation of SVPWM-based DTC for an induction motor takes place using XSG and MATLAB/Simulink. The simulation integrates switching patterns from various SVPWM sectors together with a

torque estimator that uses a low pass filter along with the PI controller. The above-designed model is synthesized by Xilinx Synthesis Tool (XST) followed by an implementation procedure using Xilinx Plan Ahead software. The illustration in Figure 11 shows both the FPGA internal arrangement along with its I/O pin interface.

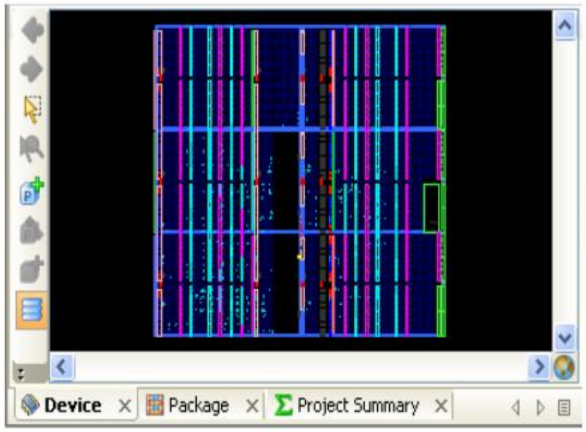

Fig 11: Internal structure of FPGA

VI. Conclusion

This paper established a dynamic control structure design along with simulation for three phase induction motor drives. The high-performance DTC-SVM with low pass filter eliminates all traditional DTC disadvantages such as variable switching frequency and torque and flux ripples as well as current distortions. The paper demonstrates simulation outcomes for the proposed concept.

References

[1] T.G.Habetler, F.Profumo, M.Pastorelli," Direct Torque control of induction machines using space vector modulation," IEEE Transactions on Inductrial Applications, vol.28:1045-1053, 1992.

[2] T.Abe, F.Profumo, G.Griva, and T.Habetler, "Evaluation of a high performance induction motor drives using space vector modulation,"Electromotion Journal, vol.2: pp.79-86, 1995.

[3] C.Lascu, I. Boldea and F.Blaabjerg,"A modified direct torque control (DTC) for induction motor sensorless drive,"Conference Record of IEEE-IAS'98, vol.1, pp. 415-422, 1998.

[4] D.Casadei, G.Serra, and A.Tani," Stator flux vector control for high performance induction motor drives using space vector modulation", Electromotion Journal, vol.2, no.2, pp.79-86, 1995.

[5] Lahoucine Idkhajine, Eric Monmassion, et al,"Fully Integrated FPGA-Based Controller for Synchronous Motor Drive", IEEE Transactions on Industrial Electronics, Vol.56, No.10, pp. 4006-4017, Oct 2009.

[6] Manohar and Deepak, "Drive for Unipolar BLDC Motor based on SEPIC Converter", Journal of Engineering Technology and Sciences, Vol. 01, Issue 04, December 2024, pp: 12-17, DOI: https://doi.org/10.5281/zenodo.14539749

[7] Ashok Naidu and Deepak, "Positioning Capacitors and Distributed Gen Units for Multi-Objective Optimization", Journal of Science Engineering Technology and Management Science, Vol. 02, Issue 02, February 2025, pp: 18-20, DOI: https://doi.org/10.5281/zenodo.14952696

[8] M.W.Naouar, E. Monmasson, and A.A>Naassani,"FPGA-based current controllers for AC machine drives-A review",IEEE Transactions on Industrial Electronics, Vol.54, No.4, pp.1907- 1925, Aug.2007.

[9] J.J.Rodriguez-Andina, M.J.Moure, and M.D.Valdes,"Features, design tools, and application domains of FPGAs", IEEE Transactions on Industrial Electroncis, Vol.54, No.4, pp.1810-1823, Aug.2007.

[10] E.Monmasson, M.N.Cirstea, at al," FPGA Design Methodology for Industrial Control Systems- a Review", IEEE Transaction on Industrial Electronics, Vol.54, No.4, pp.1824-1842, Aug.2007.

[11] Habetler, T.G., Profumo, F., and Pastorelli.M," Direct torque control of induction machines over a wide speed range", Proceedings of IEEE-IAS Conference, pp.600-606, 1992.

[12] Casadei, D., Serra, G., and Tani, A.,"Implementation of a direct control algorithm for induction motors based on discrete space vector modulation", IEEE Transactions on Power Electronics, vol.15, pp.769-777, 2000.

[13] Tsung-Po Chen., Yen-Shin Lai., and Chang-Huan Liu."A new space vector modulation technique for inverter control",Power Electronics Specialist Conference, vol.2, pp.777-782, 1999.

[14] B.K.Bose, Power Electronics and AC Drives (Prentice- Hall, 1986).